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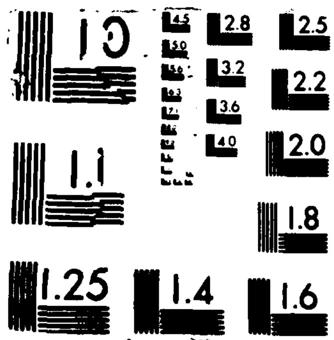
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FOREIGN TECHNOLOGY DIVISION

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(Selected Portions)

by

Zhang Yong, Gao Guangzhen, et al.

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HUMAN TRANSLATION

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A SUPERCONDUCTING MAGNET SYSTEM FOR FREE-ELECTRON CYCLOTRON MASER

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The superconducting magnet system is a important part of the free-electron cyclotron maser. In tris paper a new super conducting magnet system is designed and tested. It consists of a main superconducting magnet, a gradient superconducting magnet, a normal magnet, a cryostat and some other accessories. The advantages of the designed magnet system are small in size, high stable magnet field and suitable field profile. It is very suitable for 4 mm wave free-electron cyclotron maser.

I. INTRODUCTION

As is commonly known: the wave length and magnetic field strength of a free-electron maser have the following relationship:

$$\lambda \approx 10.7/B_0$$

where λ is the wavelength (unit is mm), B_0 is magnetic field strength (unit is T). For example, a 4mm wavelength free-electron maser requires a magnetic field of 2.65T, a 2mm wavelength one requires a magnetic field of 5.3T. The shorter the wavelength, the stronger the magnetic field required. At present, the U.S., the Soviet Union and other countries are in the process of developing short wavelength, high-power free-electron masers which extensively employ superconducting magnets. China is in the process of developing a free-electron maser using conventional magnets; but development of shorter wavelength devices will require the use of superconducting magnets. Because of the use of pulses, conventional magnets are not expedient for making free-electron masers. Therefore, various domestic organizations are now developing free-electron masers using superconducting magnets. We integrate actual conditions, in order to develop free-electron maser technology and superconducting applications, a 4mm waveband free-electron maser was built using a superconducting magnet system.

II. DESIGN OF MAGNET SYSTEM

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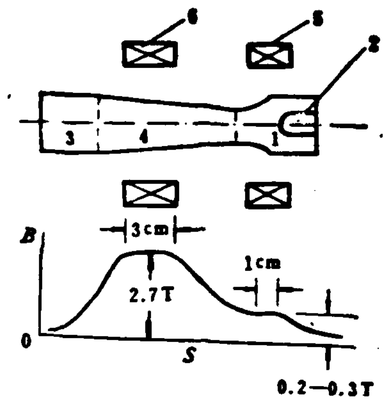

Fig. 1. Diagram of principle structures of free-electron maser and its requirements for magnetic field distribution.

Keys: 1. Cathode region, 2. Cathode, 3. Output window, 4. Resonant cavity, 5, 6. Magnets

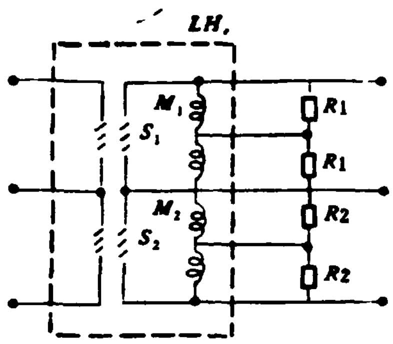

Fig. 2. Basic electrical connections of magnet system

Table 1. Design parameters of various magnets

(1) 设计参数	(2) 磁体名称	(3) 主超导磁体	(4) 梯度调制超导磁体	(5) 阴极区常规磁体
(6) 绕组几何尺寸	(7) 内半径 (mm)	70	70	60
	(8) 外半径 (mm)	133	84	210
	(9) 总 高 (mm)	126	42	180
(10) 选用导线	(11) 导线材料	NbTi φ0.4mm	NbTi φ0.4mm	Cu 1.84×6.4mm²
	(12) 铜超比	1:1	1:1	
(13) 匝 数		1036×2	954×2	620×2
(14) 最大工作电流 (A)		30	30	25
(15) 最强磁场 (T)		3	0.2	0.3
(16) 谐振工作区磁场均匀度优于		0.5%	—	1%
(17) 谐振工作区可调梯度		—	±3%	—
(18) 绕组总重量 (kg)		16	1.1	120

Keys: (1) Design parameters; (2) Magnet name; (3) Main superconducting magnet; (4) Gradient modulation superconducting magnet; (5) Cathode region conventional magnet; (6) Geometric dimensions of winding; (7) Inside radius (mm); (8) Outside radius (mm); (9) Overall height (mm); (10) Conductors selected; (11) Conductor material; (12) Copper super ratio (sic); (13) Number of turns; (14) Maximum operating current (A); (15) Strongest magnetic field (T); (16) Uniformity of resonant operating region magnetic field greater than; (17) Adjustable gradient of resonant operating region; (18) Total weight of winding (kg).

Table 2. Main geometric dimensions of Dewar vessel

	(1) 外径 (mm)	(2) 内孔直径 (mm)	(3) 高度 (mm)	(4) 容积 (l)
(5) 液氦槽	(6) 上部 421 下部 362	132	313	25
(7) 液氮槽	540	485	360	16
(8) 外杜瓦	600	90	(9) 本体 450 (10) 高度 850	

Keys: (1) Outer diameter (mm); (2) Inside hole diameter (mm); (3) Height (mm); (4) Volume (l); (5) Liquid helium tank; (6) Top 421, bottom 362; (7) Liquid nitrogen tank; (8) Outer Dewar; (9) Main part; (10) Height

III. EXPERIMENTAL RESULTS

At the end of 1984 test manufacturing of a 4mm waveguide superconducting magnet system was completed and testing was carried out. The test results made clear that the main superconducting magnet can provide a uniform magnetic field with a strength of 0-3T within a 3 cm resonant cavity core region. Uniformity is greater than 0.5%. The gradient regulated superconducting magnets have relatively good ability to alter the resonant cavity core region magnetic field gradient. With the aid of a superconducting switch, the main superconducting magnets and gradient regulated superconducting magnets can both accomplish superconducting closed-loop operation thereby achieving a height stabilized magnetic field. Typical magnetic configuration distribution curve is shown in Fig. 3. The solid line in the figure is the combined magnetic field distribution curve for a main superconducting magnet and a conventional magnet. The broken line is the magnetic field distribution curve after the superconducting magnet has gone through gradient regulation, the maximum magnetic field gradient in the resonant cavity is approximately 3%. This basically conforms to the requirements of a 4mm waveguide free-electron maser.

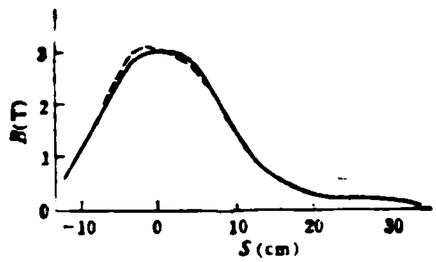

Fig. 3. Typical magnetic configuration distribution curve

A liquid helium evaporation test was conducted on a Dewar in a closed-loop operating superconducting magnet system and the results are shown in Fig. 4. Fig. 4. makes clear that under calm, stationary conditions, liquid helium evaporation rate is approximately 0.05 liter/h, under conditions where liquid replenishment is not carried out, the experiment continued for 216h, i.e., 9 days.

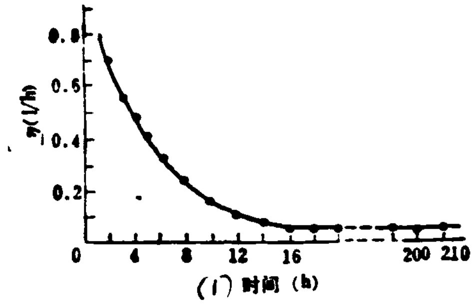

Fig. 4. Measurement curve of liquid helium evaporation rate in Dewar
Key: (1) Time (h)

All the experiments made clear that the maser which was developed uses a superconducting magnet system to satisfy design requirements and furthermore it has advantages such as the volume is low, the magnetic field is stable, the magnetic configuration can be regulated and its use is convenient. It will provide an essential part for China's development of a short wavelength free-election maser.

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